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ORIGINAL ARTICLE

From the Mediterranean to Yungas and Patagonia. Dispersal of the non-native gastropod *Rumina decollata* in Argentina

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Abstract

Rumina decollata is a land snail native to the Mediterranean region that expanded its distribution to several regions of Africa, Asia and the Americas due to accidental or purposely introductions. In Argentina, it was reported in 1988 in the outskirts of Buenos Aires City, and expanded its distribution thenceforth. This facultative self-fertilizer is omnivorous and presents high resistance to extreme climatic conditions facilitating the establishment and colonization of new environments. It is considered an invasive species, crop pest and predator of native invertebrates in several countries; it is also a host of *Aelurostrongylus abstrusus* and *Toxocara cati,* two cat parasites able to affect humans. As *R. decollata* inhabits mostly private gardens, it is difficult to do extensive sampling. So, we performed a citizen science project through social media to update its distribution in Argentina. As a result, we got 696 records from 179 cities and towns in 16 provinces and the Autonomous City of Buenos Aires, throughout the country from Patagonia to Northern Argentina. We here present the first record of *R. decollata* for eight new provinces and 166 new localities, so that the extreme localities currently confirmed in the country are > 2100 km apart, over different ecoregions, from sea level to 1900 m above sea. This snail inhabits urban and peri-urban areas and it is likely that it colonizes natural environments in a near future due to its high dispersal capacity. Our data confirm that *Rumina decollata* has spread rapidly in Argentina during the last three decades.

Keywords Citizen science · Invasive species · Distribution · Gastropoda · Achatinidae

Introduction

Rumina Risso, 1826 (Stylommatophora: Achatinidae) is a genus of terrestrial gastropods native to the Mediterranean region with facultative selfing, omnivorous feeding habits and a decollate shell; i.e., a shell breaking off from the first shell whorls resulting in a truncated apex (Fig. 1) (Batts 1957; Prevot et al. 2013; Quintana Cardona 2017; Rau et al. 2022). The morphospecies currently considered within the genus are *R. decollata* (Linnaeus, 1758), *R. saharica* Pallary, 1901, and *R. iamonae* Quintana Cardona, 2017 (Prevot et al. 2013, 2015; Quintana Cardona 2017). The status of *R. paivae* (Lowe, 1860) is dubious because it was not supported by molecular or morphological data (Prévot et al. 2013, 2015). Among these, *R. decollata*, native to northern Africa, southern France, Italy, the western Balkan and the Iberian Peninsula, enlarged its range by both accidental and intended human spread to at least 16 countries and islands of Europe, Asia, Africa, and the Americas (a comprehensive map and references in Prévot et al. 2014).

Beyond the general, theoretical concern about the dispersion of any non-native species (Essl et al. 2020, and references therein), in some locations *R. decollata* has become an agricultural pest, a host of the parasites *Aelurostrongylus abstrusus* (Railliet, 1898) and *Toxocara cati* Schrank, 1788, or a serious threat to native fauna (Mas-Coma and Montoliu 1986; Cowie 2001; Tupen and Roth 2001; Barker and Efford 2002; Matsukuma and Takeda 2009; Matamoros 2014; Cardillo et al. 2016, 2018; Landal et al. 2019). Due to its omnivorous feeding habit, it is a facultative predator on native invertebrates or it competes for resources and habitat

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Fig. 1 Living adult specimen of *Rumina decollata* (Linnaeus, 1758) with the decollated apex from Bahía Blanca, Argentina. Scale bar: 5 mm

(Cowie 2001; Barker and Efford 2002). As a predator, it devours snails, slugs, invertebrate eggs, and annelids in addition to causing damage to ornamental plants and vegetables (Batts 1957; Fisher 1966; Dundee 1986; Mc Donnell et al. 2016). In its native range, *R. decollata* inhabits rather dry places and calcareous soils, often occurring in waste ground, disturbed habitats and dry scrubby or rocky terrain (Kerney and Cameron 1979; Moreno-Rueda 2002). Though a thermophilic xeroresitant snail (Quintana Cardona 2017), it shows a high adaptability that allows it to colonize different habitats and get to be abundant in gardens and orchards.

Invasive alien species are defined as species introduced to areas outside their native range that become successfully established and cause substantial impacts on the new environment (Colautti and MacIsaac 2004; Dueñas et al. 2021). They are a major driver of global change and a main cause of biodiversity loss (Davis and Thompson 2000; Essl et al. 2020). The biological features of *R. decollata* that favour its success in colonizing and setting in natural environments (e.g., an omnivorous diet, high reproductive potential, capability for self-fertilization, and adaptability) mean that it has a strong potential to negatively affect native flora and fauna, agriculture, and health. Therefore, it meets the conditions to be considered an invasive species.The lack of records of *R. decollata*, limited to scattered localities in some countries, could be a reflection of poor sampling.

In Argentina—a large country of 2.78 million square kilometres, with diverse landscapes and climatic regimes—*R. decollata,* was previously reported from 16 localities from only eight out of its 24 jurisdictions (23 provinces and a federal district): Buenos Aires province (Miquel 1988; Virgillito 2012); Autonomous City of Buenos Aires (Virgillito 2012); La Pampa and Mendoza (De Francesco and Lagiglia 2007); Córdoba (Reyna and Gordillo 2018); and recently in Northern Patagonia (Río Negro and Chubut provinces; Pérez and Tissot 2021) and Misiones (near the country's north-eastern border with Brazil; Rau et al. 2022). The identity of the species present in Argentina, *R. decollata*, was determined considering morphological and molecular data (Carr 2022; Prevot et al. 2013; Rau et al. 2022). It was included in the Argentinian "Official list of exotic species potentially invasive and cryptogenic" with the category of *restricted species of mandatory control* (i.e., a species with high environmental and socioeconomic impact, and limited or no productive use) (Argentina, Ministerio de Ambiente y Desarrollo Sostenible 2021a, b). Although not yet considered a pest of agricultural importance (Argentina, Sistema Nacional de Vigilancia y Monitoreo de Plagas 2021), it could become a problem in the near future (De Francesco and Lagiglia 2007; Reyna and Gordillo 2018).

The aim of this study was to carry out the widest possible assessment of the geographic distribution of *R. decollata* in Argentina. Considering that 1) *R. decollata* was already known to have a wide but seemingly scattered geographic range in the country, from near the northeastern boundary with Brazil to some localities in northern Patagonia, 2) it is easily distinguishable, 3) it is often recognized as a problem for garden and orchard plants, and 4) it usually thrives in private properties not easily accessible to researchers, this case seemed appropriate to attempt a citizen science project through social media. Such a study strategy was also applied to the distribution of the same species in the Osaka Prefecture, Japan (1905 km^2) (Ishida 2020) and of other non-native species in Hungary (Páll-Gergely et al. 2019; Turóci et al. 2020).

Citizen science, defined as scientific research involving public participation and collaboration (ACSA 2020) is a powerful tool to gather distributional information on species where sampling is complicated, expensive or time-consuming (Silvertown 2009; Páll-Gergely et al. 2019; Werenkraut et al. 2020). The widespread use of internet and particularly social media provide a handy way to reach public and get information. It is also a means of increasing people awareness of environmental issues (Dickinson et al. 2012; Werenkraut et al. 2020).

Methods

We performed a mixed citizen science approach to update the distribution of *R. decollata* in Argentina. We first published a post on Facebook on 1 and 7 October 2019 in the personal profiles of three of us (Pizá, Guerrero Spagnuoli and Dop) and shared it in several Facebook pages of specialist groups in Argentina: Asociación Argentina de Malacología (Argentine Association of Malacology), Biólogos de la UNS (Biologists from Universidad Nacional del Sur), Biólogos y Biólogas de la Argentina (Biologists from Argentina). The posted flyer included two photographs for the species identification and two email addresses for reporting the occurrences (Online Resource: Fig. S1). In December 2019,

we presented a poster at the 3rd Argentine Congress of Malacology (Online Resource: Fig. S2) to present the project to the malacological community. Finally, we re-published the post on Facebook on 8 March and 1 April 2021.

We received records as personal communications (mainly from colleagues, relatives and friends), emails, comments on the posts and private messages. We answered the emails, comments and private messages with a google form (https://forms.gle/znvR2ANyUuBy7N9e6) designed to specify the geographic location and gather additional information about habitat that each respondent could contribute about the species. The survey included the request to upload one photograph of the snail sighted to check the correctness of the record.

We considered "confirmed localities" those with at least one photo-verified record and "probable localities" those records without photo.

We approximated geographic coordinates using Google Maps and estimated the uncertainty of the locations with the point-radius method (Wieczorek et al. 2004). A geographical distribution map for *R. decollata* in Argentina was developed using QGIS software version 3.20.1 (QGIS.org 2021).

Results

The four posts on Facebook were shared over 12,000 times. By 20 July 2022, we have received around 340 comments, 500 private messages and 1200 emails.

We received 664 survey responses, 401 of which included photos. We discarded three surveys: one without photo describing a different species and two (0.5%) included photos corresponding to misidentifications of the species with *Bulimulus bonariensis* (Rafinesque, 1833) and *Plagiodontes strobelii* (Doering, 1875 [1877]). We obtained 32 additional photo-verified records through direct messages or emails.

As a result, we registered 690 records from 174 "confirmed localities (cities and towns)" and 5 "probable localities" (6 records) in 16 provinces and the federal district of the Autonomous City of Buenos Aires after checking data and photographs, or physical material (Online resource: Table S1).

According to our results, *R. decollata* currently is broadly distributed across 20 degrees of latitude (Fig. 2), from North Patagonia (43° S) up to Jujuy province (23° S), and from the Atlantic coast (seaside cities in Buenos Aires provinces at 56° W) to the Andean precordillera (70° W) in the Neuquén province; the southern and northern extreme records were located 2130 km away in a straight line. The recorded altitude range covers from near sea level in the eastern Pampas to about 1900 m above sea level in the San Juan province. It seems to be absent from the Austral Patagonia region to the south of 43° S latitude (provinces of Tierra del Fuego, Santa Cruz, and southern Chubut).

About half of the records of presence of this non-native snail (341 out of 696) came from the Autonomous City of Buenos Aires (71 records) plus its surrounding urban conglomerate called the Greater Buenos Aires (270 records), both added together constituting the megacity known as the Metropolitan Area of Buenos Aires.

Other 131 records (18.8% of the total) were gathered from our residence city (Bahía Blanca, Buenos Aires province), where personal contact and checking are easier. The remaining 224 reports (32.18%) informed on the presence of the decollate snail in 16 provinces, with 1 to 38 records by province.

Rumina decollata is here recorded for the first time from 167 cities or towns over 16 Argentine provinces, eight of

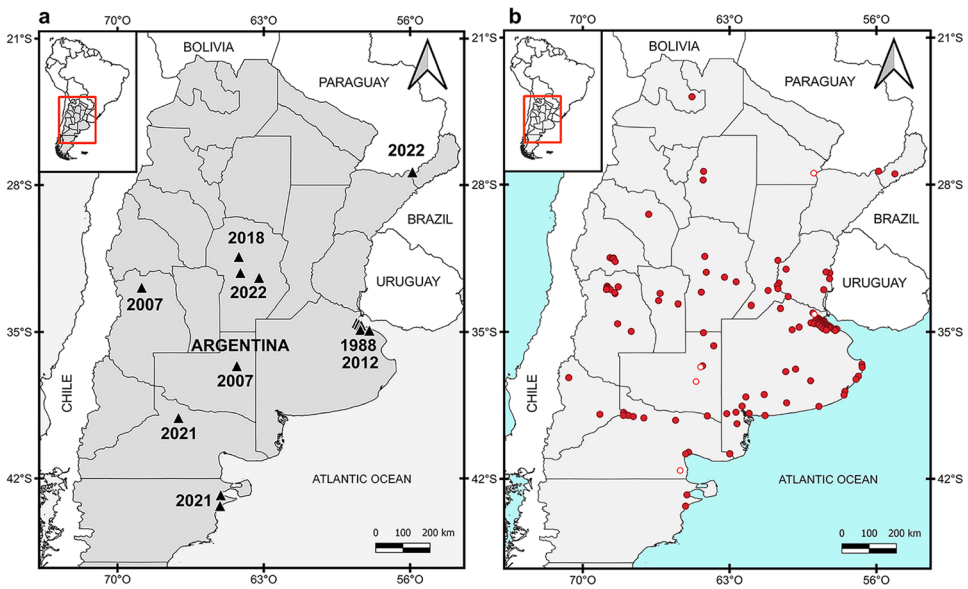

Fig. 2 Distribution map of *Rumina decollata* in Argentina. **a** 17 previous records. **b** Original records obtained in this study. Red filled circles: confirmed localities (at least one photo-verified record). Red open circles: probable localities (records without photo)

which were not previously mentioned in the literature (Jujuy, Santiago del Estero, La Rioja, San Luis, San Juan, Santa Fe, Entre Ríos and Neuquén). It is probable that the species is also present in Resistencia, Chaco province, from where we received two independent records not fully corroborated due to lack of photographs.

The vast majority of new records were from urban and peri-urban areas; 95% of them came from private gardens or public places (sidewalks, squares, parks) but *R. decollata* was also recorded from urban vegetable gardens (4.4%), wastelands (2.2%) and semi-natural environments on the outskirts of cities (2.4%). There were no records from wild protected areas.

Discussion

The first record of *R. decollata* in Argentina was from the suburbs near the border of Buenos Aires city (Miquel 1988). One of us (NJC) also found it in the 80 s, about 600 km to the south of Miquel's record, as an incipient population on the sides of the railway tracks in Bahía Blanca; 35 years later this snail is very common and abundant in the gardens of this city and suburban fields.

Previous catalogues of Argentine land snails (Parodiz 1957; Fernández 1973) did not mention the presence of this species; so, the decollate snail was probably introduced in the early–mid 1980s. According to our results, this species spread rapidly in the last three decades, as the current range of distribution extends from Patagonia to the Yungas (warm rainforests) in northern Argentina (2130 km away). In California (USA) the natural dispersal rate of *R. decollata* was calculated to be around 80 m/year over an irrigated area (Fisher et al. 1980) and 33 m/year in a non-irrigated one (Tupen and Roth 2001). The accidental anthropogenic dispersal was otherwise estimated at 3500 m/year in Japan (Matsukuma and Takeda 2009). Terrestrial snails can disperse both naturally or by human activities, but the accidental spreading through transport of biological material (ornamental plants, seeds, horticultural products, soil, etcetera) is usually the main mechanism of long range dispersal (Aubry et al. 2006; Matsukuma and Takeda 2009; Däumer et al. 2012). To illustrate the magnitude of the dispersal of this species, we estimated a maximum rough rate of 37,900 m/year considering the first published record (Buenos Aires city suburbs) and the current furthest one (Ledesma, Jujuy province). However, this rate should be considered with caution because the distribution of *R. decollata* is sporadic and the anthropogenic dispersion routes in Argentina are unknown.

Rumina decollata was also deliberately introduced to several countries as a biological control agent against *Cornu aspersum* (Müller, 1874) and other snails, with ineffective results and serious environmental consequences (Tupen and Roth 2001; Cowie et al. 2009; Mc Donnell et al. 2016; Nielsen et al. 2017), but we do not know that there has been any such initiative in Argentina.

Based on DNA sequences, Prévot et al. (2014) stated that all the populations of the nominal species *R. decollata* recorded outside their native range grouped together with the clade previously recognized as the dark morph, even though this morph is supposed to be outcompeted when sympatric with the light morph in its native area. The photographs of living specimens received showed variable body and foot coloration, so we could establish that not all the specimens corresponded to the dark morph (Fig. 1).

The current known distribution of *R. decollata* in Argentina spans multiple biogeographic provinces (defined according to Olson et al. 2001) with significant climatic differences, as the arid Patagonian Steppe, the Argentine Monte, Dry Chaco and Espinal ecoregions, and humid regions like the Humid Pampas, the Paraná flooded savannah, Southern Cone Mesopotamian savannah, Alto Parana Atlantic Forest and the Yungas. Therefore, in addition to significantly expanding the record of this species over most of the area of the country, our data illustrate the vast adaptive ability of the invader.

Although the decollate snails are active in temperatures ~ 10 to 25 °C with more than 75% relative humidity (Matsukuma and Takeda 2009), they can develop a thick epiphragm allowing consequential dormancy during periods of extremely stringent conditions of humidity or temperature (Batts 1957; Moreno-Rueda 2002; Selander and Hudson 1976).

Rumina decollata is known to predate on a variety of land snails (Barker and Efford 2002). The interaction of this species with the local snail fauna was not yet studied, but it is to be noted that 26% of the surveyed people informed a reduction of garden populations of *Cornu aspersum* and slugs they subjectively related to the increase of *R. decollata* populations. There are also some preliminary observations by a researcher indicating a negative impact of *R. decollata* on the native land snail *Bulimulus bonariensis* (Ana C. Díaz, pers. comm.).

The vast majority of the gathered information in Argentina refers to snails inhabiting urban environments, mainly private gardens, where we can assume less demanding conditions and best shelter conditions, but Pérez and Tissot (2021) also reported the existence of large populations (over 1000 snails) in a peri-urban, non-irrigated waste dump in an arid Patagonian area (Bwk in Köppen-Geiger classification), with only 240 mm annual precipitation and 14.4 °C mean annual temperature.

The huge disparity of records of *R. decollata* from different regions of Argentina could be partially explained by the very uneven demography throughout the country. Nearly

half of our records (341 out of 686) came from the Buenos Aires Metropolitan Area. This is a major consolidated urban conglomeration—i.e., an economically and culturally linked urban population— of 13285 km^2 comprising the Autonomous City of Buenos Aires and, totally or partially, another 40 urbanized or semi-urbanized districts around it. With 16.8 million inhabitants, this megacity constitutes 35.5% of the country's total population (47.3 million people) (Brinkhoff 2022). A similar scheme is repeated in the other 22 Argentine provinces, i.e., > 30% of the population living in each provincial capital, the 31 largest urban agglomerations in Argentina being inhabited by almost 70% of the total population (Argentina, Ministerio del Interior 2011); 91.9% of the Argentine population is then urban, well above the world average (55.3%) and higher than Latin America average (84.1%) (United Nations, Population Division 2019). When the strictly urban population and the area it occupies are discounted, the non-urban regions of Argentina—more than 2.77 million km^2— turn out to have a mean density of only 1.38 inhabitants per square kilometer. Therefore, it was not surprising that we exclusively received contributions from people living in urban centers, with little or no information on snail populations from agricultural fields or natural areas. *Rumina decollata* is not considered a crop pest in Argentina, but is perceived as a problem for ornamental and orchard plants; 15% of the surveyed people explicitly mentioned the use of different methods to locally control this species.

The complex process of dispersal, settlement and proliferation of an invader becoming a pest depends of a wide set of ecological, historical and political constraints (Venette 2015). *Rumina decollata* was reported only from isolated places in some countries; e.g., in Israel it remains apparently restricted to the back yard of the Terra Sancta monastery in Jerusalem (Roll et al. 2009). Early detection and an effective control action can eradicate an incipient settlement, as in the case of the elimination of a small population of *R. decollata* introduced to Cape Town, South Africa, in the 1990s, through a quick but undocumented campaign (Herbert 2010). Regrettably, this is not the condition registered in Argentina, where *R. decollata* has colonized most of country to the north of 43° S in just over 30 years.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11756-022-01293-3.

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Authors' contributions All authors contributed to the study conception and design. JP, JGS and NSD performed the data collection and the analyses. JP wrote the first draft of the manuscript; NJC critically revised and improved it. All authors read and approved the final manuscript.

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Data availability All data are provided as online resource.

Declarations

Ethics approval Not applicable.

Conflicts of interest The authors declare that they have no conflict of interest.

Consent to participate Citizen scientists were informed about the purpose of the research and the use of the data provided.

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